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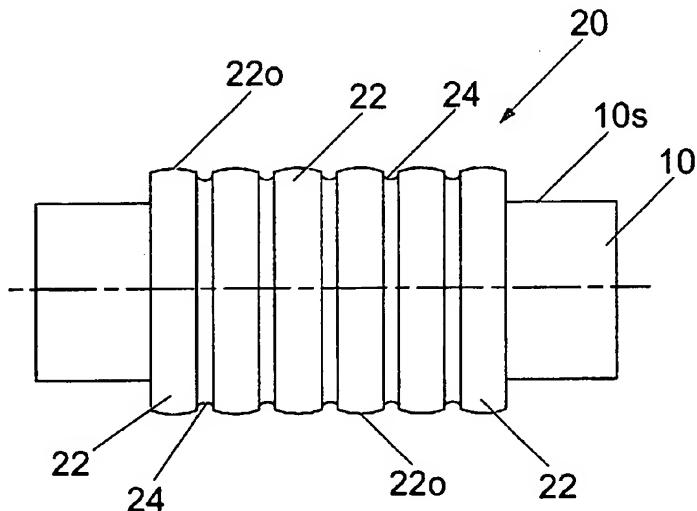
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(54) Title: DEVICE AND METHOD TO SEAL BOREHOLES



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(57) Abstract: Apparatus and methods are described that are particularly suited for creating a seal in a borehole annulus. In one embodiment, an outer surface 10s of an expandable conduit (10) is provided with a formation (20) that includes an elastomeric material (e.g. a rubber) that can expand and/or swell when the material comes into contact with an actuating agent (e.g. water, brine, drilling fluid etc.). The expandable conduit (10) is located inside a second conduit (e.g. a pre-installed casing, liner or open borehole) and radially expanded. The actuating agent can be naturally occurring in the borehole or can be injected or pumped therein to expand or swell the elastomeric material to create the seal.

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*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

## DEVICE AND METHOD TO SEAL BOREHOLES

1

2

3 The present invention relates to apparatus and  
4 methods for sealing an annulus in a borehole. The  
5 present invention can also be used to seal and lock  
6 expandable tubular members within cased, lined, and  
7 in particular, open-hole boreholes.

8

9 It is known to use expandable tubular members, e.g.  
10 liners, casing and the like, that are located in a  
11 borehole and radially expanded in situ by applying a  
12 radial expansion force using a mechanical expander  
13 device or an inflatable element, such as a packer.  
14 Once the expandable member has been expanded into  
15 place, the member may not contact the conduit (e.g.  
16 liner, casing, formation) in which it is located  
17 along the entire length of the member, and a seal is  
18 generally required against the liner, casing or  
19 formation to prevent fluid flow in an annulus created  
20 between the expandable member and the liner, casing  
21 or formation, and also to hold differential pressure.  
22 The seal also helps to prevent movement of the

1 expandable member that may be caused by, for example,  
2 expansion or contraction of the member or other  
3 tubular members within the borehole, and/or  
4 accidental impacts or shocks.

5

6 When running and expanding in open-hole applications  
7 or within damaged or washed-out casing, liner etc,  
8 the diameter of the borehole or the casing, liner etc  
9 may not be precisely known as it may vary over the  
10 length of the borehole because of variations in the  
11 different materials in the formation, or variations  
12 in the internal diameter of the downhole tubulars.  
13 In certain downhole formations such as washed-out  
14 sandstone, the size of the drilled borehole can vary  
15 to a large extent along the length or depth thereof.

16

17 According to a first aspect of the present invention,  
18 there is provided a seal for use in a borehole, the  
19 seal comprising an elastomeric material that is  
20 capable of expanding upon contact with an actuating  
21 agent.

22

23 According to a second aspect of the present  
24 invention, there is provided a method of creating a  
25 seal in a borehole, the method comprising the steps  
26 of providing an elastomeric material in the borehole  
27 and exposing the material to an actuating agent that  
28 causes the elastomeric material to expand.

29

30 The seal is preferably expanded in an annulus to seal  
31 the annulus or a portion thereof.

1  
2 The elastomeric material is typically a rubber. The  
3 elastomeric material can be NITRILE™, VITON™, AFLAS™,  
4 Ethylene-propylene rubbers (EPM or EPDM) or KALREZ™,  
5 although other suitable materials may also be used.  
6 Any elastomeric material may be used. The choice of  
7 elastomeric material will largely depend upon the  
8 particular application and the actuating agent.  
9 Also, the fluids that are present downhole will also  
10 determine which elastomeric material or actuating  
11 agent can be used.

12  
13 The actuating agent typically comprises a water- or  
14 mineral-based oil or water. Production and/or  
15 drilling fluids (e.g. brine, drilling mud or the  
16 like) may also be used. Hydraulic oil may be used as  
17 the actuating agent. Any fluid that reacts with a  
18 particular elastomeric material may be used as the  
19 actuating agent. The choice of actuating agent will  
20 depend upon the particular application, the  
21 elastomeric material and the fluids that are present  
22 downhole.

23  
24 The actuating agent may be naturally occurring  
25 downhole, or can be injected or pumped into the  
26 borehole. Alternatively, a container (e.g. a bag) of  
27 the actuating agent can be located at or near the  
28 elastomeric material where the container bursts upon  
29 radial expansion of the conduit. Thus, the actuating  
30 agent comes into contact with the elastomeric  
31 material causing it to expand and/or swell.

1

2 The elastomeric material is typically applied to an  
3 outer surface of a conduit. The conduit can be any  
4 downhole tubular, such as drill pipe, liner, casing  
5 or the like. The conduit is preferably capable of  
6 being radially expanded, and is thus typically of a  
7 ductile material.

8

9 The conduit can be a discrete length or can be in the  
10 form of a string where two or more conduits are  
11 coupled together (e.g. by welding, screw threads  
12 etc). The elastomeric material can be applied at two  
13 or more axially spaced-apart locations on the  
14 conduit. The elastomeric material is typically  
15 applied at a plurality of axially spaced-apart  
16 locations on the conduit.

17

18 The conduit is typically radially expanded. The  
19 conduit is typically located in a second conduit  
20 before being radially expanded. The second conduit  
21 can be a borehole, casing, liner or other downhole  
22 tubular.

23

24 The elastomeric material can be at least partially  
25 covered or encased in a non-swelling and/or non-  
26 expanding elastomeric material. The non-swelling  
27 and/or non-expanding elastomeric material can be an  
28 elastomer that swells in a particular fluid that is  
29 not added or injected into the borehole, or is not  
30 naturally occurring in the borehole. Alternatively,  
31 the non-swelling and/or non-expanding elastomeric

1 material can be an elastomer that swells to a lesser  
2 extent in the naturally occurring, added or injected  
3 fluid.

4

5 As a further alternative, a non-swelling polymer  
6 (e.g. a plastic) may be used in place of the non-  
7 swelling and/or non-expanding elastomeric material.  
8 The non-swelling polymer can be TEFLON™, RYTON™ or  
9 PEEK™.

10

11 The elastomeric material may be in the form of a  
12 formation. The formation can comprise one or more  
13 bands of the elastomeric material, the bands  
14 typically being annular. Alternatively, the  
15 formation may comprise two outer bands of a non-  
16 swelling and/or non-expanding elastomeric material  
17 (or other rubber or plastic) with a band of swelling  
18 elastomeric material therebetween. A further  
19 alternative formation comprises one or more bands of  
20 elastomeric material that are more or less covered or  
21 encased in a non-swelling and/or non-expanding  
22 elastomeric (or other) material. At least a portion  
23 of the elastomeric material is typically not covered  
24 by the non-swelling and/or non-expanding material.  
25 The uncovered portion of the elastomeric material  
26 typically facilitates contact between the material  
27 and the actuating agent. Other formations may also  
28 be used.

29

30 The elastomeric material typically swells upon  
31 contact with the actuating fluid due to absorption of

1 the fluid by the material. Alternatively, or  
2 additionally, the elastomeric material can expand  
3 through chemical attack resulting in a breakdown of  
4 cross-linked bonds.

5

6 The elastomeric material typically expands and/or  
7 swells by around 5% to 200%, although values outwith  
8 this range are also possible. The expansion and/or  
9 swelling of the elastomeric material can typically be  
10 controlled. For example, restricting the amount of  
11 actuating agent can control the amount of expansion  
12 and/or swelling. Also, reducing the amount of  
13 elastomeric material that is exposed to the actuating  
14 agent (e.g. by covering or encasing more or less of  
15 the material in a non-swelling material) can control  
16 the amount of expansion and/or swelling. Other  
17 factors such as temperature and pressure can also  
18 affect the amount of expansion and/or swelling, as  
19 can the surface area of the elastomeric material that  
20 is exposed to the actuating agent.

21

22 Optionally, the expansion and/or swelling of the  
23 elastomeric material can be delayed for a period of  
24 time. This allows the conduit to be located in the  
25 second conduit and radially expanded before the  
26 elastomeric material expands and/or swells. Chemical  
27 additives can be combined with the base formulation  
28 of the swelling elastomeric material to delay the  
29 swelling for a period of time. The period of time  
30 can be anything from a few hours to a few days. The  
31 particular chemical additive that is used typically

1 depends upon the structure of the base polymer in the  
2 elastomeric material. Pigments such as carbon black,  
3 glue, magnesium carbonate, zinc oxide, litharge and  
4 sulphur are known to have a slowing or delaying  
5 influence on the rate of swelling.

6

7 As an alternative to this, a water- or other alkali-  
8 soluble material can be used, where the soluble  
9 material is at least partially dissolved upon contact  
10 with a fluid, or by the alkalinity of the water.

11

12 The method typically includes the additional step of  
13 applying the elastomeric material to an outer surface  
14 of a conduit. The conduit can be any downhole  
15 tubular, such as drill pipe, liner, casing or the  
16 like. The conduit is preferably capable of being  
17 radially expanded, and is thus typically of a ductile  
18 material.

19

20 The method typically includes the additional step of  
21 locating the conduit within a second conduit. The  
22 second conduit may comprise a borehole, casing, liner  
23 or other downhole tubular.

24

25 The method typically includes the additional step of  
26 applying a radial expansion force to the conduit.  
27 The radial expansion force typically increases the  
28 inner and outer diameters of the conduit. The radial  
29 expansion force can be applied using an inflatable  
30 element (e.g. a packer) or an expander device (e.g. a  
31 cone). The conduit can be rested on top of the

1       inflatable element or the expander device as it is  
2       run into the second conduit.

3

4       The method typically includes the additional steps of  
5       providing an expander device and pushing or pulling  
6       the expander device through the conduit. The  
7       expander device is typically attached to a drill  
8       string, coiled tubing string, wireline or the like,  
9       but can be pushed or pulled through the second  
10      conduit using any conventional means.

11

12      Alternatively, the method typically includes the  
13      additional steps of providing an inflatable element  
14      and actuating the inflatable element. The inflatable  
15      element can be attached to a drill string, coiled  
16      tubing string or wireline (with a downhole pump).  
17      Optionally, the method may include one, some or all  
18      of the additional steps of deflating the inflatable  
19      element, moving it to another location, and re-  
20      inflating it to expand a further portion of the  
21      conduit.

22

23      The method optionally includes the additional step of  
24      injecting or pumping the actuating agent into the  
25      borehole.

26

27      The method optionally includes the additional step of  
28      temporarily anchoring the conduit in place. This  
29      provides an anchor point for the radial expansion of  
30      the conduit. A packer, slips or the like can be used  
31      for this purpose. The inflatable element is

1     optionally used to expand a portion of the conduit  
2     against the second conduit to act as an anchor point.  
3

4     Embodiments of the present invention shall now be  
5     described, by way of example only, with reference to  
6     the accompanying drawings, in which:-

7         Fig. 1 is a first embodiment of a formation  
8         applied to an outer surface of a conduit;  
9         Fig. 2 is a second embodiment of a formation  
10        applied to an outer surface of a conduit;  
11        Fig. 3a is a third embodiment of a formation  
12        applied to an outer surface of a conduit; and  
13        Fig. 3b is a cross-sectional view through a  
14        portion of the conduit of Fig. 3a.

15  
16     Referring to the drawings, Fig. 1 shows a conduit 10  
17     that is provided with a first embodiment of a  
18     formation 20 on an outer surface 10s thereof. The  
19     formation 20 includes a plurality of bands 22 that  
20     are rounded on their outer edges 22o and are joined  
21     by a plurality of valleys 24 therebetween. The bands  
22     22 and valleys 24 provide an overall ribbed profile  
23     to the formation 20.

24  
25     Formation 20 is typically comprised of an elastomeric  
26     material that can expand and/or swell due to contact  
27     with an actuating agent such as a fluid. The  
28     expansion and/or swelling of the elastomeric material  
29     results in increased dimensional properties of the  
30     elastomeric material in the formation 20. That is,  
31     the material forming the bands 22 and valleys 24 will

1 expand or swell in both the longitudinal and radial  
2 directions, the amount of expansion or swelling  
3 depending on the amount of actuating agent, the  
4 amount of absorption thereof by the elastomeric  
5 material and the amount of the elastomeric material  
6 itself. It will also be appreciated that for a given  
7 elastomeric material, the amount of swelling and/or  
8 expansion is a function not only of the type of  
9 actuating agent, but also of physical factors such as  
10 pressure, temperature and the surface area of  
11 material that is exposed to the actuating agent.

12

13 The expansion and/or swelling of the elastomeric  
14 material can take place either by absorption of the  
15 actuating agent into the porous structure of the  
16 elastomeric material, or through chemical attack  
17 resulting in a breakdown of cross-linked bonds. In  
18 the interest of brevity, use of the terms "swell" and  
19 "swelling" or the like will be understood also to  
20 relate to the possibility that the elastomeric  
21 material may additionally, or alternatively expand.

22

23 The elastomeric material is typically a rubber  
24 material, such as NITRILE™, VITON™, AFLAS™, Ethylene-  
25 propylene rubbers (EPM or EPDM) and KALREZ™. The  
26 actuating agent is typically a fluid, such as  
27 hydraulic oil or water, and is generally an oil- or  
28 water-based fluid. For example, brine or other  
29 production or drilling fluids (e.g. mud) can be used  
30 to cause the elastomeric material to swell. The  
31 actuating agent used to actuate the swelling of the

1       elastomeric material can either be naturally  
2       occurring in the borehole itself, or specific fluids  
3       or chemicals that are pumped or injected into the  
4       borehole.

5

6       The type of actuating agent that causes the  
7       elastomeric material to swell generally depends upon  
8       the properties of the material, and in particular the  
9       hardening matter, material or chemicals used in the  
10      elastomeric material.

11

12      Table 1 below gives examples of fluid swell for a  
13      variety of elastomeric materials, and the extent to  
14      which they swell when exposed to certain actuating  
15      agents.

16

17      Table 1

18

Material	Swelling Media (at 300°F)	
	Expansion with Hydraulic Oil	Expansion With Water
NITRILE™	15%	10%
VITON™	10%	20%
AFLAS™	30%	12%
EPDM	200%	15%
KALREZ™	5%	10%

19

20      As indicated above, the amount of swelling of the  
21      elastomeric material depends on the type of actuating  
22      agent used to actuate the swelling, the amount of  
23      actuating agent and the amount and type of

1       elastomeric material that is exposed to the actuating  
2       agent. The amount of swelling of the elastomeric  
3       material can be controlled by controlling the amount  
4       of fluid that is allowed to contact the material and  
5       for how long. For example, the material may only be  
6       exposed to a restricted amount of fluid where the  
7       material can only absorb this restricted amount.  
8       Thus, swelling of the elastomeric material will stop  
9       once all the fluid has been absorbed by the material.

10

11      The elastomeric material can typically swell by  
12      around 5% (or less) to around 200% (or more),  
13      depending upon the type of elastomeric material and  
14      actuating agent used. If the particular properties  
15      of the material and the amount of fluid that the  
16      material is exposed to are known, then it is possible  
17      to predict the amount of expansion or swelling. It  
18      is also possible to predict how much material and  
19      fluid will be required to fill a known volume.

20

21      The structure of the formation 20 can be a  
22      combination of swelling or expanding and non-swelling  
23      or non-expanding elastomers, and the outer surfaces  
24      of the formation 20 may be profiled to enable maximum  
25      material exposure to the swelling or expanding  
26      medium. In the interest of brevity, non-swelling and  
27      non-expanding elastomeric material will be referred  
28      to commonly by "non-swelling", but it will be  
29      appreciated that this may include non-expanding  
30      elastomeric materials also.

31

1 The formation 20 is typically applied to the outer  
2 surface 10s of the conduit 10 before it is radially  
3 expanded. Conduit 10 can be any downhole conduit  
4 that is capable of sustaining plastic and/or elastic  
5 deformation, and can be a single length of, for  
6 example, liner, casing etc. However, conduit 10 may  
7 be formed of a plurality of lengths of casing, liner  
8 or the like that are coupled together using any  
9 conventional means, e.g. screw threads, welding etc.

10

11 Formation 20 is typically applied at axially spaced-  
12 apart locations along the length of conduit 10,  
13 although it may be provided continuously over the  
14 length of the conduit 10 or a portion thereof. It  
15 will be appreciated that the elastomeric material  
16 will require space into which it can swell, and thus  
17 it is preferable to have at least some spacing  
18 between the formations 20. The elastomeric material  
19 of the or each formation 20 is typically in a solid  
20 or relatively solid form so that it can be attached  
21 or bonded to the outer surface 10s and remain there  
22 as the conduit 10 is run into the borehole, casing,  
23 liner or the like.

24

25 Once the borehole has been drilled, or in the case of  
26 a borehole that is provided with pre-installed  
27 casing, liner or the like, conduit 10 is located in  
28 the borehole, casing, liner or the like and radially  
29 expanded using any conventional means. This can be  
30 done by using an inflatable element (e.g. a packer)  
31 or an expander device (e.g. a cone) to apply a radial

1 expansion force. The conduit 10 typically undergoes  
2 plastic and/or elastic deformation to increases its  
3 inner and outer diameters.

4

5 The expansion of conduit 10 is typically not  
6 sufficient to expand the outer surface 10s into  
7 direct contact with the formation of the borehole or  
8 pre-installed casing, liner or the like, although  
9 this may not always be the case. For example,  
10 certain portions of the conduit 10 may contact the  
11 formation at locations along its length due to normal  
12 variations in the diameter of the borehole during  
13 drilling, and/or variations in the diameter of the  
14 conduit 10 itself. Thus, an annulus is typically  
15 created between the outer surface 10s and the  
16 borehole, casing, liner etc.

17

18 It will be appreciated that the elastomeric material  
19 in the or each formation 20 may begin to swell as  
20 soon as the conduit 10 is located in the borehole as  
21 the fluid that actuates the swelling may be naturally  
22 occurring in the borehole. In this case, there is  
23 generally no requirement to inject chemicals or other  
24 fluids to actuate the swelling of the elastomeric  
25 material.

26

27 However, the elastomeric material may only swell when  
28 it comes into contact with particular fluids that are  
29 not naturally occurring in the borehole and thus the  
30 fluid will require to be injected or pumped into the  
31 annulus between the conduit 10 and the borehole,

1 casing, liner or the like. This can be done using  
2 any conventional means.

3

4 As an alternative to this, a bag or other such  
5 container (not shown) that contains the actuating  
6 fluid can be attached to the outer surface 10s at or  
7 near to the or each formation 20. Indeed, the bag or  
8 the like can be located over the or each formation  
9 20. Thus, as the conduit 10 is radially expanded,  
10 the bag ruptures causing the actuating fluid to  
11 contact the elastomeric material.

12

13 It will be appreciated that it is possible to delay  
14 the swelling of the elastomeric material. This can  
15 be done by using chemical additives in the base  
16 formulation that causes a delay in swelling. The  
17 type of additives that may be added will typically  
18 vary and may be different for each elastomeric  
19 material, depending on the base polymer used in the  
20 material. Typical pigments that can be added that  
21 are known to delay or having a slowing influence on  
22 the rate of swelling include carbon black, glue,  
23 magnesium carbonate, zinc oxide, litharge and  
24 sulphur.

25

26 As an alternative, the elastomeric material can be at  
27 least partially or totally encased in a water-soluble  
28 or alkali-soluble polymeric covering. The covering  
29 can be at least partially dissolved by the water or  
30 the alkalinity of the water so that the actuating  
31 agent can contact the elastomeric material

1       thereunder. This can be used to delay the swelling  
2       by selecting a specific soluble covering that can  
3       only be dissolved by chemicals or fluids that are  
4       injected into the borehole at a predetermined time.

5

6       The delay in swelling can allow the conduit 10 to be  
7       located in the borehole, casing, liner or the like  
8       and expanded into place before the swelling or a  
9       substantial part thereof takes place. The delay in  
10      swelling can be any length from hours to days.

11

12      As the elastomeric material swells, it expands and  
13      thus creates a seal in the annulus. The seal is  
14      independent of the diameter of the borehole, casing,  
15      liner or the like as the material will swell and  
16      continue to swell upon absorption of the fluid to  
17      substantially fill the annulus between the conduit 10  
18      and the borehole, casing, liner or the like in the  
19      proximity of the formation 20. As the elastomeric  
20      material swells and continues to do so, it will come  
21      into contact with the formation of the borehole,  
22      casing, liner or the like and will go into a  
23      compressive state to provide a tight seal in the  
24      annulus. Not only does the elastomeric material act  
25      as a seal, but it will also tend to lock the conduit  
26      10 in place within the borehole, casing, liner or the  
27      like.

28

29      Upon swelling, the elastomeric material retains  
30      sufficient mechanical properties (e.g. hardness,  
31      tensile strength, modulus of elasticity, elongation

1 at break etc) to withstand differential pressure  
2 between the borehole and the inside of the liner,  
3 casing etc. The mechanical properties that are  
4 retained also ensure that the elastomeric material  
5 remains bonded to the conduit 10. The mechanical  
6 properties can be maintained over a significant time  
7 period so that the seal created by the swelling of  
8 the elastomeric material does not deteriorate over  
9 time.

10

11 It will be appreciated that the mechanical properties  
12 of the elastomeric material can be adjusted or tuned  
13 to specific requirements. Chemical additives such as  
14 reinforcing agents, carbon black, plasticisers,  
15 accelerators, activators, anti-oxidants and pigments  
16 may be added to the base polymer to have an effect on  
17 the final material properties, including the amount  
18 of swell. These chemical additives can vary or  
19 change the tensile strength, modulus of elasticity,  
20 hardness and other factors of the elastomeric  
21 material.

22

23 The resilient nature of the elastomeric material can  
24 serve to absorb shocks and impacts downhole, and can  
25 also tolerate movement of the conduit 10 (and other  
26 downhole tubular members) due to expansion and  
27 contraction etc.

28

29 Referring to Fig. 2, there is shown an alternative  
30 formation 30 that can be applied to an outer surface  
31 40s of a conduit 40. Conduit 40 can be the same or

1 similar to conduit 10. As with formation 20,  
2 formation 30 can be applied at a plurality of axially  
3 spaced-apart locations along the length of the  
4 conduit 40. Conduit 40 may be a discrete length of  
5 downhole tubular that is capable of being radially  
6 expanded, or can comprise a length of discrete  
7 portions of downhole tubular that are coupled  
8 together (e.g. by welding, screw threads etc).  
9

10 The formation 30 comprises two outer bands 32, 34 of  
11 a non-swelling elastomeric material with an  
12 intermediate band 36 of a swelling elastomeric  
13 material therebetween. It will be appreciated that  
14 the intermediate band 36 has been provided with a  
15 ribbed or serrated outer profile to provide a larger  
16 amount of material (i.e. an increased surface area)  
17 that is exposed to the actuating fluid that causes  
18 swelling. The use of the outer bands 32, 34 of a  
19 non-swelling elastomeric material can allow the  
20 amount of swelling of the intermediate band 36 of the  
21 elastomeric material to be controlled. This is  
22 because the two outer bands 32, 34 can limit or  
23 otherwise restrict the amount of swelling of the  
24 elastomeric material (i.e. band 36) in the axial  
25 directions. Thus, the swelling of the material will  
26 be substantially constrained to the radial direction.  
27

28 The non-swelling elastomeric material can be an  
29 elastomer that swells in a particular fluid that is  
30 not added or injected into the borehole, or is not  
31 naturally occurring in the borehole. Alternatively,

1 the non-swelling elastomeric material can be an  
2 elastomer that swells to a lesser extent in the  
3 naturally occurring, added or injected fluid. For  
4 example, and with reference to Table 1 above, if  
5 hydraulic oil is being used as the actuating fluid,  
6 then the elastomeric material could be EPDM (which  
7 expands by around 200% in hydraulic oil) and the non-  
8 swelling elastomeric material could be KALREZ™ as  
9 this only swells by around 5% in hydraulic oil.

10

11 As a further alternative, a non-swelling polymer  
12 (e.g. a plastic) may be used in place of the non-  
13 swelling elastomeric material. For example, TEFLON™,  
14 RYTON™ or PEEK™ may be used.

15

16 It will be appreciated that the term "non-swelling  
17 elastomeric material" is intended to encompass all of  
18 these options.

19

20 The outer bands 32, 34 of a non-swelling elastomeric  
21 material also provides a mechanism by which the  
22 swelling of the elastomeric material in intermediate  
23 band 36 can be controlled. For example, when the  
24 conduit 10 is radially expanded, the bands 32, 34 of  
25 the non-swelling elastomeric material will also  
26 expand, thus creating a partial seal in the annulus  
27 between the outer surface 10s of the conduit 10 and  
28 the borehole, casing, liner or the like. The partial  
29 seal reduces the amount of fluid that can by-pass it  
30 and be absorbed by the swelling elastomeric material  
31 of band 36. This restriction in the flow of fluid

1 can be used to delay the swelling of the elastomeric  
2 material in band 36 by restricting the amount of  
3 fluid that can be absorbed by the material, thus  
4 reducing the rate of swelling.

5

6 The thickness of the bands 32, 34 in the radial  
7 direction can be chosen to allow either a large  
8 amount of fluid to seep into band 36 (i.e. by making  
9 the bands relatively thin) or a small amount of fluid  
10 (i.e. by making the bands relatively thick). If the  
11 bands 32, 34 are relatively thick, a small annulus  
12 will be created between the outer surface of the  
13 bands 32, 34 and the borehole etc, thus providing a  
14 restriction to the fluid. The restricted fluid flow  
15 will thus cause the elastomeric material to swell  
16 more slowly. However, if the bands 32, 34 are  
17 relatively thin, then a larger annulus is created  
18 allowing more fluid to by-pass it, and thus providing  
19 more fluid that can swell the elastomeric material.

20

21 Additionally, the two outer bands 32, 34 can also  
22 help to prevent extrusion of the swelling elastomer  
23 material in band 36. The swelling elastomeric  
24 material in band 36 typically gets softer when it  
25 swells and can thus extrude. The non-swelling  
26 material in bands 32, 34 can help to control and/or  
27 prevent the extrusion of the swelling elastomeric  
28 material. It will be appreciated that the bands 32,  
29 34 reduce the amount of space into which the swelling  
30 material of band 36 can extrude and thus by reducing  
31 the space into which it can extrude, the amount of

1 extrusion can be controlled or substantially  
2 prevented. For example, if the thickness of the  
3 bands 32, 34 is such that there is very little or no  
4 space into which the swelling elastomeric material  
5 can extrude into, then this can stop the extrusion.  
6 Alternatively, the thickness of the bands 32, 34 can  
7 provide only a relatively small space into which the  
8 swelling elastomeric material can extrude into, thus  
9 substantially controlling the amount of extrusion.

10

11 Figs. 3a and 3b show a further formation 50 that can  
12 be applied to an outer surface 60s of a conduit 60.  
13 Conduit 60 can be the same as or similar to conduits  
14 10, 40 and may be a discrete length of downhole  
15 tubular that is capable of being radially expanded,  
16 or can comprise a length of discrete portions of  
17 downhole tubular that are coupled together (e.g. by  
18 welding, screw threads etc).

19

20 Formation 50 comprises a number of axially spaced-  
21 apart bands 52 that are typically annular bands, but  
22 this is not essential. The bands 52 are located  
23 symmetrically about a perpendicular axis so that the  
24 seals created upon swelling of the elastomeric  
25 material within the bands hold pressure in both  
26 directions.

27

28 The bands 52 are typically lip-type seals. As can be  
29 seen from Fig. 3b in particular, the bands 52 have an  
30 outer covering 52o of a non-swelling elastomer, and  
31 an inner portion 52i of a swelling elastomeric

1 material. One end 52a of the band 52 is open to  
2 fluids within the borehole, whereas the outer  
3 covering 52o encases the remainder of the elastomeric  
4 material, thus substantially preventing the ingress  
5 of fluids.

6

7 The swelling of the elastomeric material in inner  
8 portion 52i is constrained by the outer covering 52o,  
9 thus forcing the material to expand out end 52a.  
10 This creates a seal that faces the direction of  
11 pressure. With the embodiment shown in Fig. 3a, four  
12 seals are provided, with two facing in a first  
13 direction and two facing in a second direction. The  
14 second direction is typically opposite the first  
15 direction. This provides a primary and a back-up  
16 seal in each direction, with the seal facing the  
17 pressure.

18

19 The outer covering 52o can also help to prevent or  
20 control the extrusion of the elastomeric material in  
21 inner portion 52i as described above.

22

23 Thus, certain embodiments of the present invention  
24 provide apparatus and methods for creating seals in a  
25 borehole that use the swelling properties of  
26 elastomeric materials to create the seals. Certain  
27 embodiments of the present invention can also prevent  
28 swelling of the material until the conduit to which  
29 it is applied has been radially expanded in situ.

30

1     Modifications and improvements may be made to the  
2     foregoing without departing from the scope of the  
3     present invention.

## 1        CLAIMS

2  
3        1. A seal for use in a borehole, the seal  
4        comprising an elastomeric material that is capable  
5        of expanding or swelling upon contact with an  
6        actuating agent.

7

8        2. A seal according to claim 1, wherein the  
9        elastomeric material comprises a rubber.

10

11        3. A seal according to either preceding claim,  
12        wherein the elastomeric material is NITRILE™,  
13        VITON™, AFLAS™, Ethylene-propylene rubbers (EPM or  
14        EPDM) or KALREZ™.

15

16        4. A seal according to any preceding claim,  
17        wherein the actuating agent comprises a water- or  
18        mineral-based oil or water.

19

20        5. A seal according to any preceding claim,  
21        wherein the actuating agent is naturally occurring  
22        downhole, or is injected or pumped into the  
23        borehole.

24

25        6. A seal according to any one of claims 1 to 4,  
26        wherein a container of the actuating agent is  
27        located at or near the elastomeric material where  
28        the container bursts upon radial expansion of the  
29        conduit.

30

1       7. A seal according to any preceding claim,  
2       wherein the elastomeric material is applied to an  
3       outer surface of a conduit.

4

5       8. A seal according to claim 7, wherein the  
6       conduit is capable of being radially expanded.

7

8       9. A seal according to claim 7 or claim 8, wherein  
9       the elastomeric material is applied at two or more  
10      axially spaced-apart locations on the conduit.

11

12      10. A seal according to any one of claims 7 to 9,  
13      wherein the conduit is radially expanded.

14

15      11. A seal according to claim 10, wherein the  
16      conduit is located in a second conduit before being  
17      radially expanded.

18

19      12. A seal according to any preceding claim,  
20      wherein the elastomeric material is at least  
21      partially covered or encased in a non-swelling  
22      and/or non-expanding elastomeric material, or a non-  
23      swelling polymer.

24

25      13. A seal according to any preceding claim,  
26      wherein the elastomeric material swells upon contact  
27      with the actuating fluid due to absorption of the  
28      fluid by the material.

29

30      14. A seal according to any preceding claim,  
31      wherein the elastomeric material can expand through

1       chemical attack resulting in a breakdown of cross-  
2       linked bonds.

3

4       15. A method of creating a seal in a borehole, the  
5       method comprising the steps of providing an  
6       elastomeric material in the borehole and exposing  
7       the material to an actuating agent that causes the  
8       elastomeric material to expand.

9

10      16. A method according to claim 15, including the  
11       additional step of applying the elastomeric material  
12       to an outer surface of a conduit.

13

14      17. A method according to claim 16, including the  
15       additional step of locating the conduit within a  
16       second conduit.

17

18      18. A method according to claim 16 or claim 17,  
19       wherein the method includes the additional step of  
20       applying a radial expansion force to the conduit.

21

22      19. A method according to any one of claim 15 to  
23       18, wherein the method includes the additional step  
24       of injecting or pumping the actuating agent into the  
25       borehole.

1 / 2

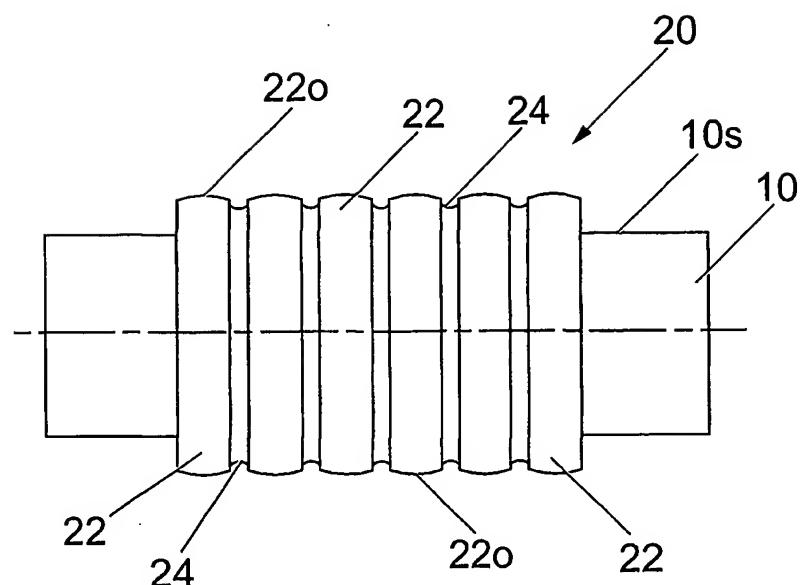


Fig. 1

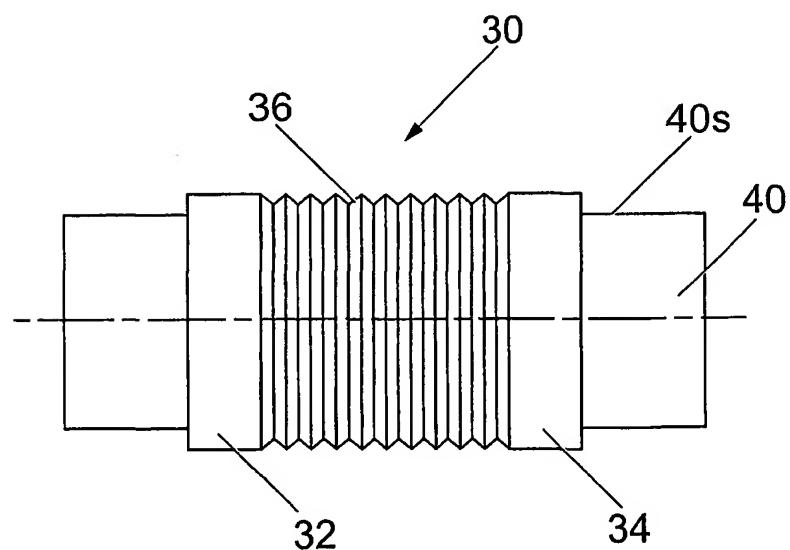
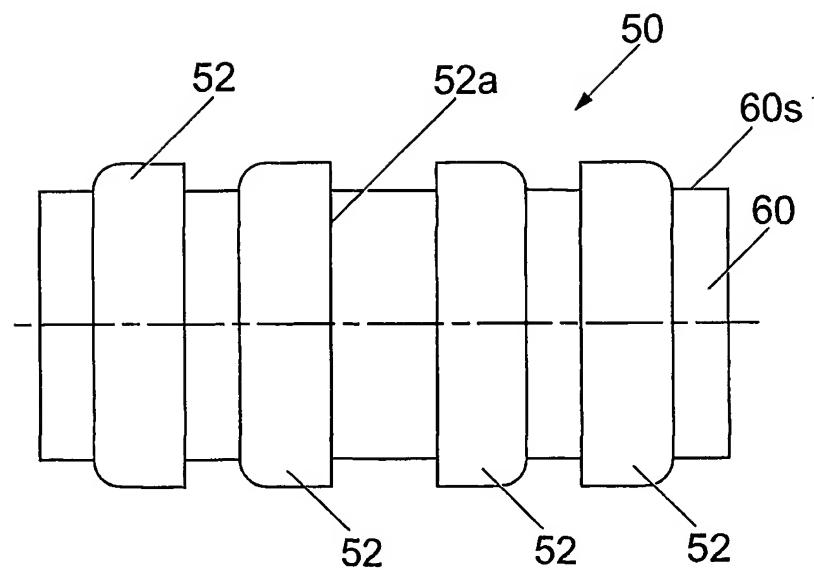
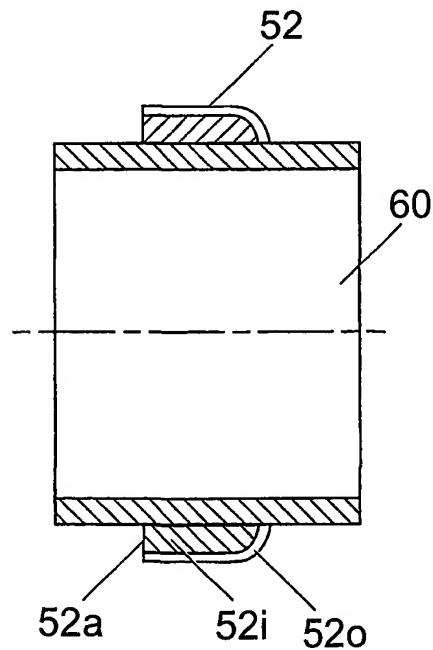


Fig. 2

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*Fig. 3a*



*Fig. 3b*

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/GB 02/00362

## A. CLASSIFICATION OF SUBJECT MATTER

IPC7: E21B 33/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2945541 A (GEORGE P. MALY ET AL), 19 July 1960 (19.07.60), column 1, line 34 - line 42; column 2, line 4 - line 16; column 3, line 10 - line 20  --	1,2,4,5,7,9, 12,13,15,16
X	US 3385367 A (PAUL KOLLMAN), 28 May 1968 (28.05.68), column 2, line 30 - line 32; column 2, line 45 - line 50; column 2, line 72, column 4, lines 57 - 75; column 5, lines 27 - 30; column 7, lines 42 - 47; column 8, lines 27 - 39; figures  --	1,2,4,5,7,9, 15-17
Y		8,10,11,18

 Further documents are listed in the continuation of Box C. See patent family annex.

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"&amp;" document member of the same patent family

Date of the actual completion of the international search

13 May 2002

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International application No.

PCT/GB 02/00362

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3918523 A (STUBER), 11 November 1975 (11.11.75), column 2, line 36 - line 52; column 3, line 29 - line 52; column 3, line 65 - line 66, figures	1,2,4,5,7,9, 12,15,16,17, 19
Y	---	8,10,11,18
Y	WO 0037766 A2 (ASTEC DEVELOPMENTS LIMITED), 29 June 2000 (29.06.00), page 1, line 8 - line 22, figures 10,11, claim 33	8,10,11,18
Y	---	
X	US 4862967 A (HARRIS), 5 Sept 1989 (05.09.89), column 2, line 36 - line 45; column 3, line 14 - line 31, figures	1,2-5,7,12, 13,15,16
X	---	
X	US 3740360 A (KENNETH H. NIMERICK), 19 June 1973 (19.06.73), column 1, line 32 - line 47; column 2, line 17 - line 26; column 5, line 15 - line 30, abstract, column 5, lines 48 - 55	1,3-5,13-15
X	---	
X	US 4836940 A (ALEXANDER), 6 June 1989 (06.06.89), column 6, line 3 - line 10; column 8, line 8 - column 9, line 2; column 9, line 45 - line 65, abstract	1,2-5,13-15
X	---	
X	US 5086841 A (REID ET AL), 11 February 1992 (11.02.92), column 1, line 10 - line 17; column 2, line 57 - column 3, line 5; column 3, line 47 - line 62	1,3-5,13-15
X	---	

**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

01/05/02

International application No.

PCT/GB 02/00362

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US	2945541	A	19/07/60	NONE	
US	3385367	A	28/05/68	NONE	
US	3918523	A	11/11/75	US 3946569 A	30/03/76
WO	0037766	A2	29/06/00	AU 1867900 A	12/07/00
				AU 1868700 A	12/07/00
				AU 1868800 A	12/07/00
				AU 1868900 A	12/07/00
				AU 1876600 A	12/07/00
				AU 1876800 A	12/07/00
				EP 1141515 A	10/10/01
				EP 1141517 A	10/10/01
				EP 1141518 A	10/10/01
				EP 1144802 A	17/10/01
				EP 1147287 A	24/10/01
				EP 1151180 A	07/11/01
				GB 2345308 A	05/07/00
				GB 2346400 A	09/08/00
				GB 2346632 A	16/08/00
				GB 2346909 A	23/08/00
				GB 2347445 A	06/09/00
				GB 9828234 D	00/00/00
				GB 9928941 D	00/00/00
				GB 9930166 D	00/00/00
				GB 9930396 D	00/00/00
				GB 9930397 D	00/00/00
				GB 9930398 D	00/00/00
				NO 20012596 A	27/07/01
				NO 20012597 A	27/07/01
				NO 20012598 A	30/07/01
				NO 20012599 A	30/07/01
				NO 20012600 A	30/07/01
				NO 20012865 A	07/08/01
				WO 0037767 A	29/06/00
				WO 0037768 A	29/06/00
				WO 0037771 A	29/06/00
				WO 0037772 A	29/06/00
				WO 0037773 A	29/06/00
				AU 2946099 A	11/10/99
				GB 0025433 D	00/00/00
				GB 2353387 A,B	21/02/01
				GB 9900835 D	00/00/00
				GB 0006215 D	00/00/00
				GB 9923783 D	00/00/00
				GB 9924189 D	00/00/00
US	4862967	A	05/09/89	NONE	
US	3740360	A	19/06/73	NONE	
US	4836940	A	06/06/89	NONE	

**INTERNATIONAL SEARCH REPORT**

Information on patent family members

01/05/02

International application No.

PCT/GB 02/00362

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5086841 A	11/02/92	US 5034139 A	23/07/91